Hal D.

VOYAGER 1 AND 2

COSMIC RAY SUBSYSTEM

Description of Jupiter Encounter Data

IN 050 9 DOC 9 thunk

Instrumentation

As its name implies, the Cosmic Ray Subsystem (CRS) was designed for cosmic ray studies (Stone et al., 1977). It consists of two High Energy Telescopes (HET), four Low Energy Telescopes (LET) and The Electron Telescope (TET). The detectors have large geometric factors (~ 0.48 to 8 cm^2 ster) and long electronic time constants (~ 24 μsec) for low power consumption and good stability. Normally, the data are primarily derived from comprehensive (ΔE_1, ΔE_2 and E) pulse-height information about individual events. Because of the high particle fluxes encountered at Jupiter and Saturn, greater reliance had to be placed on counting rates in single detectors and various coincidence rates. The detectors used for most of our work are listed in Table 1 and illustrated in Figure 1. In interplanetary space, guard counters are placed in anticoincidence with the primary detectors to reduce the background from high-energy particles penetrating through the sides of the telescopes. These guard counters were turned off in the Jovian magnetosphere when the accidental anticoincidence rate became high enough to block a substantial fraction of the desired counts. Fortunately, under these conditions the spectra were sufficiently soft that the background, due to penetrating particles, was small.

The data on proton and ion fluxes at Jupiter were obtained with the LET. The thicknesses of individual solid-state detectors in the LET and their trigger thresholds were chosen such that, even in the Jovian magnetosphere, electrons made, at most, a very minor contribution to the proton counting rates (Lupton and Stone, 1972). Dead time corrections and accidental coincidences were small (< 20%) throughout most of the magnetotail, but were substantial (> 50%) at flux maxima within 40 R_J of Jupiter. Data have been included in this package for those periods when the corrections are less than ~ 50% and can be corrected by the user with the dead time appropriate to the detector (2 to 25 μsec). The high counting rates, however, caused some baseline shift which may have raised proton thresholds significantly. In the inner magnetosphere, the L_2 counting rate was still useful because it never rolled over. This rate is due to 1.8- to 13-MeV protons penetrating L_1 (0.43 cm^2 ster) and > 9-MeV protons penetrating the shield (8.4 cm^2 ster). For an E^{-2} spectrum, the two groups would make comparable contributions; but in the magnetosphere, for the E^{-3} to E^{-4} spectrum above 2.5 MeV (McDonald et al., 1979), the contribution from protons penetrating the shield would be only 3 to 14%.

The LET $L_1L_2\overline{L_4}$ and $L_1L_2L_3$ coincidence-anticoincidence rates give the proton flux between 1.8 and 8 MeV and 3 to 8 MeV with a small alpha patricle contribution (~ 10^{-3}). Corrections are required for dead time losses in L_1, accidental L_1L_2 coincidences and anticoincidence losses from L_4. Data are given only for periods when these corrections are relatively small. In addition to the rates listed in the table, the energy lost in detectors L_1, L_2 and L_3 was measured for individual particles. For protons, this covered the energy range from 0.42 to 8.3 MeV. Protons can be identified positively by the ΔE vs. E technique, their spectra obtained and accidental coincidences greatly reduced. Because of telemetry limitations, however, only a small fraction of the events could be transmitted, and statistics become poor unless pulse-height data are averaged over a period of one hour.

HET and LET detectors share the same data lines and pulse-height analyzers; thus, the telescopes can interfere with one another during periods of high counting rates. To prevent such an interference and explore different coincidence conditions, the experiment was cycled through four operating modes, each 192 seconds long. Either the HETs or the LETs were turned on at a time. LET-D was cycled through L_1 only and L_1L_2 coincidence requirements. The TET was cycled through various coincidence conditions, including singles from the front detectors. At the expense of some time resolution, this procedure permitted us to obtain significant data in the outer magnetosphere and excellent data during the long passage through the magnetotail region.

Some of the published results from this experiment required extensive corrections for dead time, accidental coincidences and anticoincidences (Vogt et al., 1979a, 1979b; Schardt et al., 1981; Gehrels et al., 1981). These corrections can be aplied only on a case-by-case basis after a careful study of the environment and many self-consistency checks. They cannot be applied on a systematic basis and we have no computer programs to do so; therefore, data from such periods are not included in the Data Center submission. The scientists on the CRS team will, however, be glad to consider special requests if the desired information can be extracted from the data.

In order to acquaint the potential user of these data with the type of information that can be extracted from the CRS data, we are showing typical rates and fluxes in Figures 2 through 7.

Description of the Data

(1) LD1 RATE gives the nominal > 0.43-MeV proton flux $cm^{-2}s^{-1}sr^{-1}$. This rate includes all particles which pass through a 0.8 mg/cm^2 aluminum foil and deposits more than 220 keV in a 34.6 μ Si detector on Voyager 1 (209 keV, 33.9 μ on Voyager 2) Therefore, heavy ions, such as oxygen and sulfur are also detected; however, their contributin is believed to be relatiely

small. Only a small percentage of the pulses in this detector are larger than the maximum energy that can be deposited by a proton. Heavy ions would produce such large pulses, unless their energy spectra were much steeper than the proton spectrum. The true flux, F_t, can be calculated from the data:

$$F_t = \frac{F}{1 - 1.26\times10^{-4}F}$$

and corrections are small for $F < 1000\ cm^{-2}s^{-1}$.

(2) LD2 RATE is not suitable for an absolute flux determination and is given in counters per s. The detector responds to protons and ions that penetrate either (a) 0.8 mg/cm^2 Al plus 8.0 mg/cm^2 Si and lose at least 200 keV in a 35 μ Si detector (1.8 to 13 MeV) or (b) pass through > 140 mg/cm^2 Al. For an E^{-2} proton spectrum, the contributions from (a) and (b) would be about equal; however, the proton spectrum is substantially softer throughout most of the magnetosphere and the detector should respond primarily to (a). Dead time corrections are given by

$$R_t = \frac{R}{1 - 2.55\times10^{-5}R}$$

where R is the count rate in counts/s. Thus, correction to the supplied data are small for R < 4000 c/sec, but become so large in the middle magnetosphere that the magnitude of even relative intensity changes becomes uncertain.

(3) LD $L_1 . L_2 . L_4 .$ SL COINCIDENCE RATE gives the total proton flux ($cm^{-2}s^{-1}sr^{-1}$) between ~ 1.8 and ~ 8.1 MeV with a small admixture of alpha particles. Accidental coincidences become substantial at higher rates and

the flux derived from pulse-height analysis should be used if accuracy is desired.

(4) LDTRP RATE gives proton flux ($cm^{-2}s^{-1}sr^{-1}$) between 3.0 and 8.0 MeV with a small alpha particle contribution ($L_1L_2L_3$ coincidences are required).

(5) IBS4E RATE gives the electron flux ($cm^{-2}s^{-1}sr^{-1}$) for electrons with a range between 4 and 10 mm in Si; this corresponds approximately to the energy range of 2.6-5.1 MeV. Accidental coincidence and dead time corrections are generally small in the magnetotail and have not been applied to these data. Because of differences between Voyager 1 and 2, we give the average rate for HET I and II for Voyager 1 and the HET I rate for Voyager 2.

(6) IBS3E RATE is the same as (5); but the electron range falls between 10 and 16 mm of Si, or approximately 5.1-8 MeV.

(7) IBS2E RATE is the same as (5); but the electron range falls etween 16 and 22 mm of Si, or approximately 8-12 MeV.

(8) D4L RATE is not suitable for an absolute electron flux determination. This counting rate includes all pulses from detector D_4 of TET (Fig. 1) which exceed 0.5 MeV. The shielding varies with direction of incidence but is at least 1.2 cm of Si. In the Jovian environment, the detector responds primarily to electrons with energies above ~ 6 MeV. The D_4L rate is useful primarily for determining relative changes in the high-energy electron flux. This rate has a high background from the RTG. Where needed, the dead time corrections should be applied as to the LD_2 rate ($\tau \sim 2.55\times10^{-5}s$).

(9) Pulse-height Analyzed Proton Flux (FPHA) is derived from a ΔE vs. E analysis of pulses from L_1, L_2 and L_3 of LET (Fig 1) and gives the

average proton flux ($cm^{-2}s^{-1}sr^{-1}MeV^{-1}$) in six energy channels. Where required, a correction should be applied for the dead time in LD1 as follows:

$$FPHA_t = \frac{FPHA}{1 - 1.26\times10^{-4} FLD1}$$

where FPHA is the listed flux of this rate (9) and FLD1 is the flux given in rate 1. FPHA gives the most accurate value of the proton flux available from this experiment; however, the counting statistics are poorer than for the other rates because of limited sampling. Fluxes derived from rate 3 (LD) which cover the same energy range as FPHA will be higher because of poorer definition of the energy threshold, accidental coincidences and a variable, but small, background contribution.

ENERGY CHANNELS (MEV) OF FPHA

(absolute accuracy ~ 10%)

	VOYAGER 1	VOYAGER 2
1	1.829 - 2.045	1.807 - 2.001
2	2.045 - 3.104	2.001 - 3.309
3	3.104 - 3.753	3.309 - 3.984
4	3.753 - 4.530	3.984 - 4.761
5	4.530 - 6.284	4.761 - 6.041
6	6.284 - 8.091	6.041 - 8.043

Data Format

Time-history of CRS data described above is being submitted on 9-track tapes recorded at 1600 BPI. Tape marked CRSJU1 contains Voyager 1 data and the one marked CRSJU2 contains Voyager 2 data.

Each tape contains nine files. Contents of CRSJU1 are described in Table 2, and those of CRSJU2 appear in Table 3. Each file consists of a number of Flux Time-History (FTH) records. An FTH record contains a count of the number of data items (NBIN) whose time-history is included in the record, a count of the number of averaging intervals (NINT) included in the record, definitions of data items included and time-history data. Table 4 defines the structure of an FTH record in detail. These tapes were generated on an IBM System 360 computer; thus, a word consists of 32 bits, half-word 1 is the high order 16-bit field of the word and half-word 2 the low order half (bits 16-31, with the left-most or MSB numbered 0). Characters are represented in 8-bit EBCDIC byte, real numbers are represented in the IBM single precision floating point format. Length (in words) of an FTH record is given by

$$200 + (3 + 2 * \text{NBIN}) * \text{NINT} \qquad \text{NBIN} \leq 5$$

$$233 + (3 + 2 * 6) * \text{NINT} \qquad \text{NBIN} = 6$$

For all files on CRSJU1 and CRSJU2, NINT $\leq$ 96. For file 9, NINT $\leq$ 24. Thus, maximum record length is 680 words (2720 bytes) for files 1-4 and 8, 872 words (3488 bytes) for files 5-7 and 593 words (2372 bytes) for file 9.

Table 1
CRS DETECTORS USED DURING JUPITER ENCOUNTER

Detector	Shielding	Energy Range+ (MeV)	Factor ($cm^2 ster$)	Comments
PROTONS (LET):				
L1*	0.8 mg/cm^2 Aℓ	0.42-12	4.5	Also, alphas above 0.32 MeV/n
L2*	8.1 mg/cm^2 Si	1.8 -13	0.43	Through L1
	>140 mg/cm^2 Aℓ	>9	8.4	Protons through side. The intensity is comparable to those through front for E^{-2} spectrum
L1 L2 $\overline{L4}$		1.8 - 8	0.43	ΔE - E analysis
ELECTRONS (HET):				
Range: 4-10 mm Si		2.6- 5.1	1.46	Coincidence rates with good background rejections, but accidental coincidence problems at high counting rates (for details, see Stone et al., 1977).
10-16 mm Si		5.8- 8	1.25	
16-22 mm Si		8 -12	0.96	
ELECTRONS (TET):				
D4 (3 mm Si) .	~1.2 cm Si equivalent	>6	~14	Usable at higher flux than HET rates

*Single rates
+Small difference between similar detectors

Table 2. CONTENTS OF CRSJU1

FILE #	DATA ITEM	AVERAGING INTERVAL	TIME PERIOD
1	LD1 RATE	15 min.	2/28/79, 00:00, to 3/04/79, 12:00 3/06/79, 06:45, to 3/17/79, 00:00
2	LD2 RATE	15 min.	2/28/79, 00:00, to 3/09/79, 12:00
3	LD RATE	15 min.	2/28/79, 00:00, to 3/03/79, 12:00 3/07/79, 08:00, to 3/17/79, 00:00
4	LDTRP RATE	15 min.	Same as for LD RATE
* 5	BS4E RATE	15 min.	2/28/79, 00:00, to 3/03/79, 00:00 3/07/79, 08:00, to 3/17/79, 00:00
* 6	BS3E RATE	15 min.	Same as for BS4E RATE
* 7	BS2E RATE	15 min.	Same as for BS4E RATE
8	D4L RATE	15 min.	2/28/79, 00:00, to 3/04/79, 20:00 3/06/79, 02:00, to 3/08/79, 00:00
9	FPHA	1 hour	2/28/79, 00:00, to 3/03/79, 12:00 3/07/79, 08:00, to 3/17/79, 00:00

---

*These files nominally contain two quantities, the rate when guard anticoincidence is required and the rate when guard term is deleted from coincidence requirement. The experiment is in the latter state from ~ 01:15:00, March 2, 1979, to ~ 20:15:00, March 2, 1979. Note also that HET-I and HET-II data are averaged in these files.

Table 3. CONTENTS OF CRSJU2

	FILE #	DATA ITEM	AVERAGING INTERVAL	TIME PERIOD
	1	LD1 RATE	15 min.	7/03/79, 00:00, to 7/08/79, 12:00 7/11/79, 12:00, to 8/04/79, 00:00
	2	LD2 RATE	15 min.	7/03/79, 00:00, to 7/14/79, 00:00
	3	LD RATE	15 min.	7/03/79, 00:00, to 7/06/79, 00:00 7/11/79, 18:00, to 8/04/79, 00:00
	4	LDTRP RATE	15 min.	Same as LD RATE
*	5	BS4E RATE	15 min.	7/03/79, 00:00, to 7/06/79, 04:00 7/12/79, 12:00, to 8/04/79, 00:00
*	6	BS3E RATE	15 min.	Same as BS4E RATE
*	7	BS2E RATE	15 min.	Same as BS4E RATE
	8	D4L RATE	15 min.	7/03/79, 00:00, to 7/08/79, 12:00 7/11/79, 12:00, to 8/14/79, 00:00
	9	FPHA	1 hour	7/03/79, 00:00, to 7/06/79, 04:00 7/11/79, 18:00, to 8/04/79, 00:00

---

*These files nominally contain two quantities, the rate when guard anticoincidence is required and the rate when guard term is deleted from coincidence requirement. The experiment is in the latter state from ~ 12:15:00, July 12, 1979, to ~ 06:15:00, July 18, 1979.

Table 4. STRUCTURE OF FLUX TIME-HISTORY RECORD

WORD	HALFWORD	TYPE	DESCRIPTION
1	1	Integer	Number of data items contained in the record (NBIN).
	2	Integer	Number of averaging intervals (NINT) contained in the record.
3-35		character	132-character title identifies satellite and gives the start time of first averaging interval and last averaging interval in the record.
36-68		character	132-character description of first data item.
69-101		character	132-character description of second data item, if NBIN $\geq$ 2. Otherwise, not used.
102-134		character	132-character description of third data item, if NBIN $\geq$ 3. Otherwise, not used.
135-167		character	132-character description of fourth data item, if NBIN $\geq$ 4. Otherwise, not used.
168-200		character	132-character description of fifth data item, if NBIN $\geq$ 5. Otherwise, not used.
		NBIN $\leq$ 5	
201-			NINT Averaging Interval Entries (AIE). The structure of an AIE is shown in Table 5.
		NBIN = 6	
201-233		character	132-character description of sixth data item.
234-			NINT Averaging Interval Entries.

Table 5. STRUCTURE OF AVERAGING INTERVAL ENTRY

WORD	HALFWORD	TYPE	DESCRIPTION	
1	1	Integer	2-digit year	
	2	Integer	month of year	
2	1	Integer	day of month	Start time of averaging interval
	2	Integer	hour of day	
3	1	Integer	minute of hour	
	2	Integer	second of minute	
4-(3+2*NBIN)		Real	NBIN FLUX entries. Each FLUX entry is two words long. If the second word of the entry is -1.0, data for this item is not available; otherwise the first word is the value of flux and the second word contains the associated statistical error.	

REFERENCES

Gehrels, N., E.C. Stone and J.H. Trainor, "Energetic Oxygen and Sulful in the Jovian Magnetosphere," submitted to J. Geophys. Res., 1981.

Lupton, J.E., and E.C. Stone, "Measurement of Electron Detection Efficiencies in Solid-state Detectors," Nucl. Instr. and Meth. 98, 189, 1972.

McDonald, F.B., A.W. Schardt and J.H. Trainor, "Energetic Protons in the Jovian Magnetosphere," J. Geophys. Res. 84, 2579, 1979.

Schardt, A.W., F.B. McDonald and J.H. Trainor, "Energetic Particles in the Pre-dawn Magnetotail of Jupiter," J. Geophys. Res., special Voyager issue, 1981.

Stone, E.C., R.E. Vogt, F.B. McDonald, B.J. Teegarden, J.H. Trainor, J.R. Jokipii and W.R. Webber, "Cosmic Ray Investigation for the Voyager Mission: Energetic Particle Studies in the outer Heliosphere--and Beyond," Space Sci. Rev. 21, 355, 1977.

Vogt, R.E., W.R. Cook, A.C. Cummings, T.L. Garrard, N. Gehrels, E.C. Stone, J.H. Trainor, A.W. Schardt, T. Conlon, N. Lal and F.B. McDonald, "Voyager 1: Energetic Ions and Electrons in the Jovian Manetosphere," Science 204, 1003, 1979a.

Vogt, R.E., A.C. Cummings, N. Gehrels, E.C. Stone, J.H. Trainor, A.W. Schardt, T.F. Conlon and F.B. McDonald, "Voyager 2: Energetic Ions and Electrons in the Jovian Magnetosphere," Science 206, 984, 1979b.

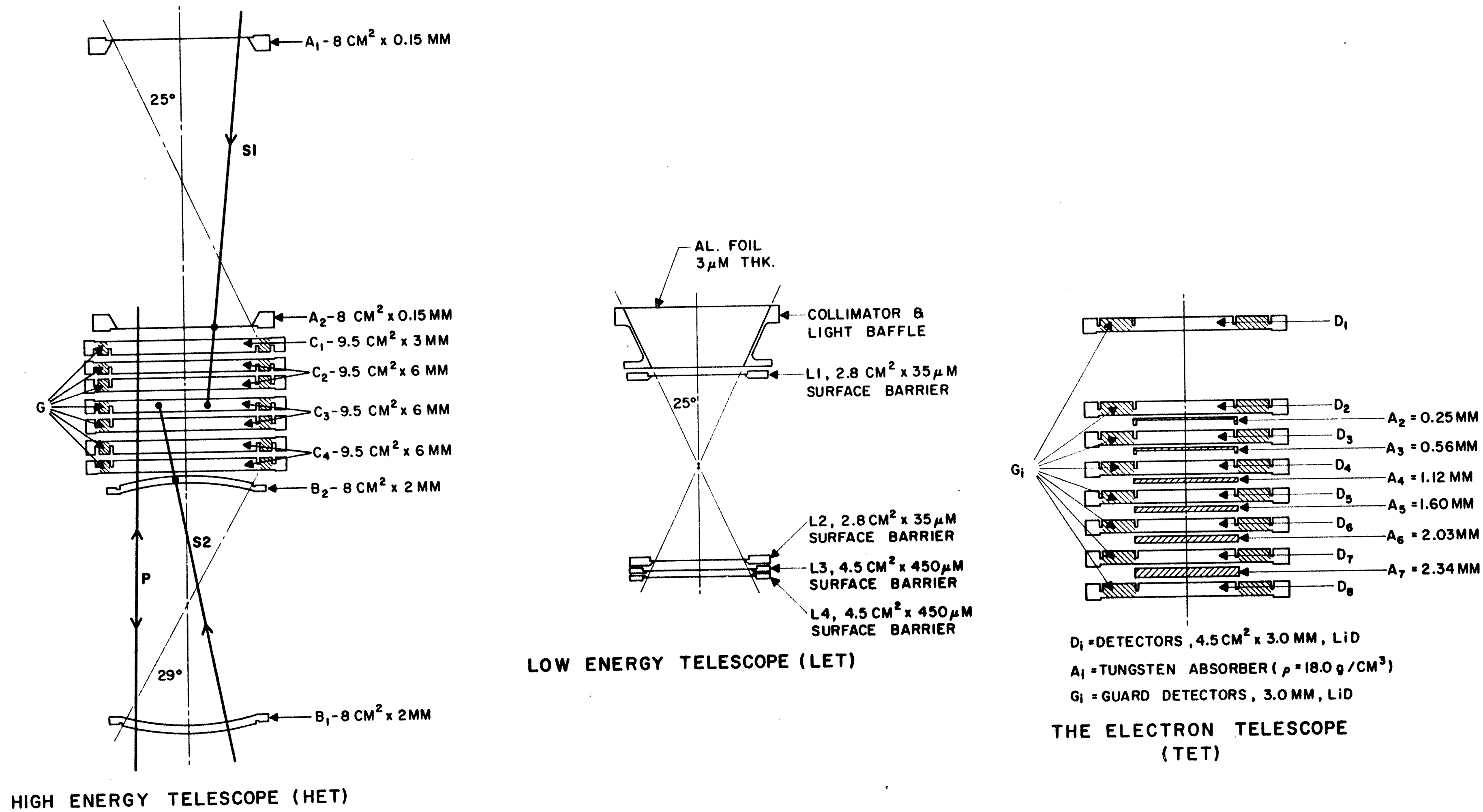

Fig. 1. Schematic diagram of the High Energy Telescope (HET), Low Energy Telescope (LET) and the Electron Telescope (TET) systems.

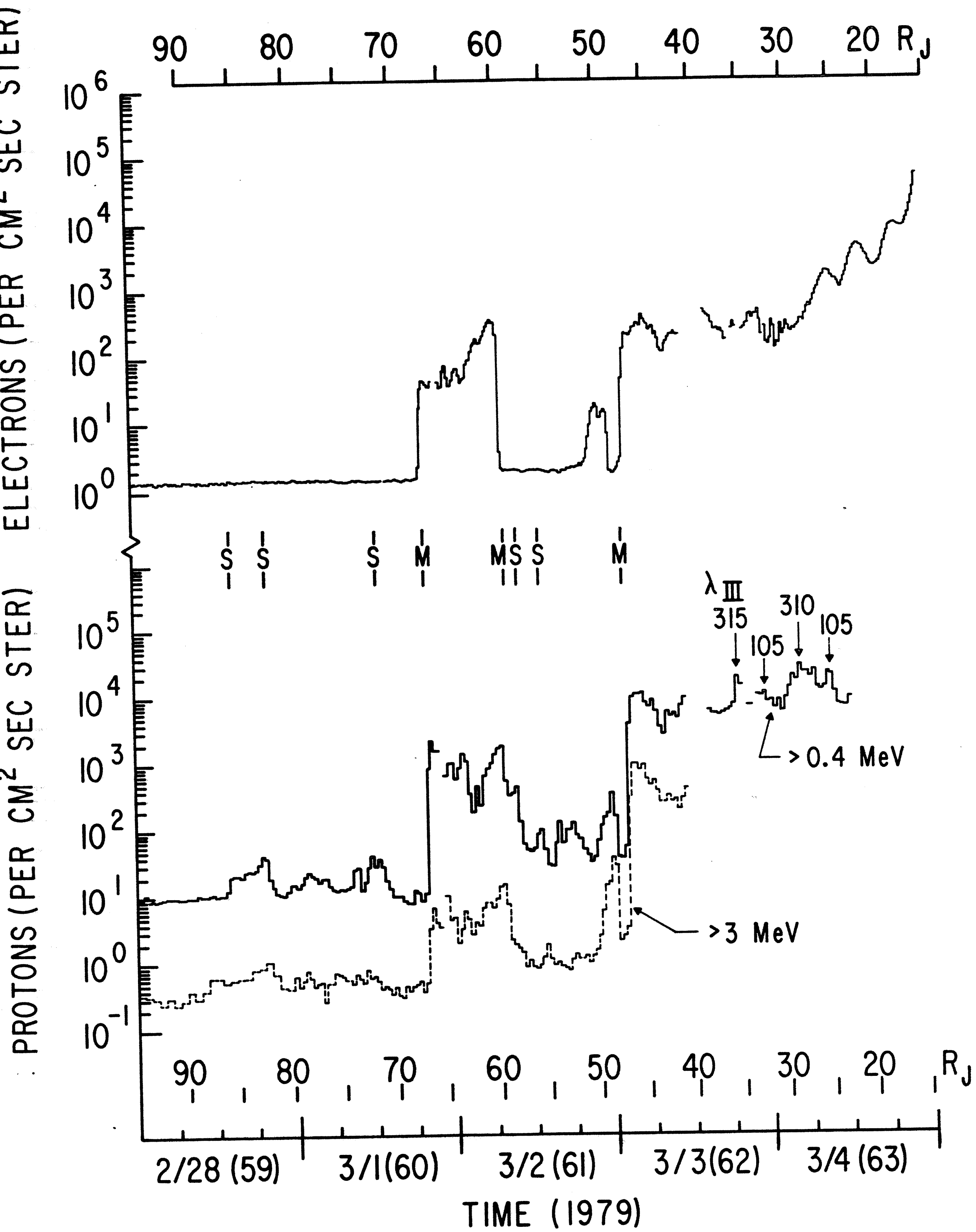

Fig. 2. Proton and > 5 MeV electron flux observed during the inbound pass of Voyager 1. Bow shock and magnetopause crossings are indicated by S and M, respectively. Jovicentric longitudes (λ_{III} 1965) of flux maxima near magnetic equatorial crossings are indicated.

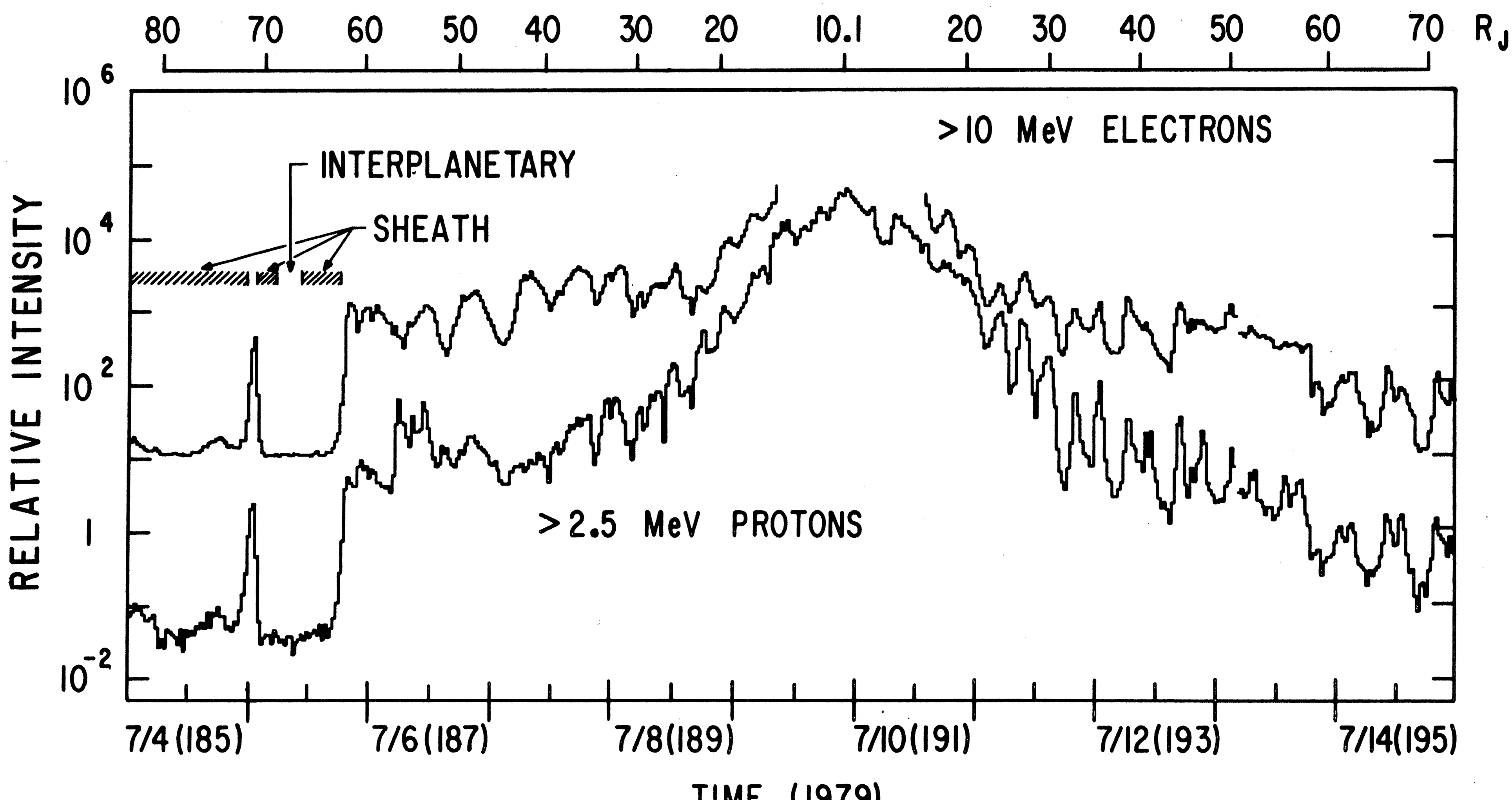

Fig. 3. Proton and electron intensities observed by Voyager 2

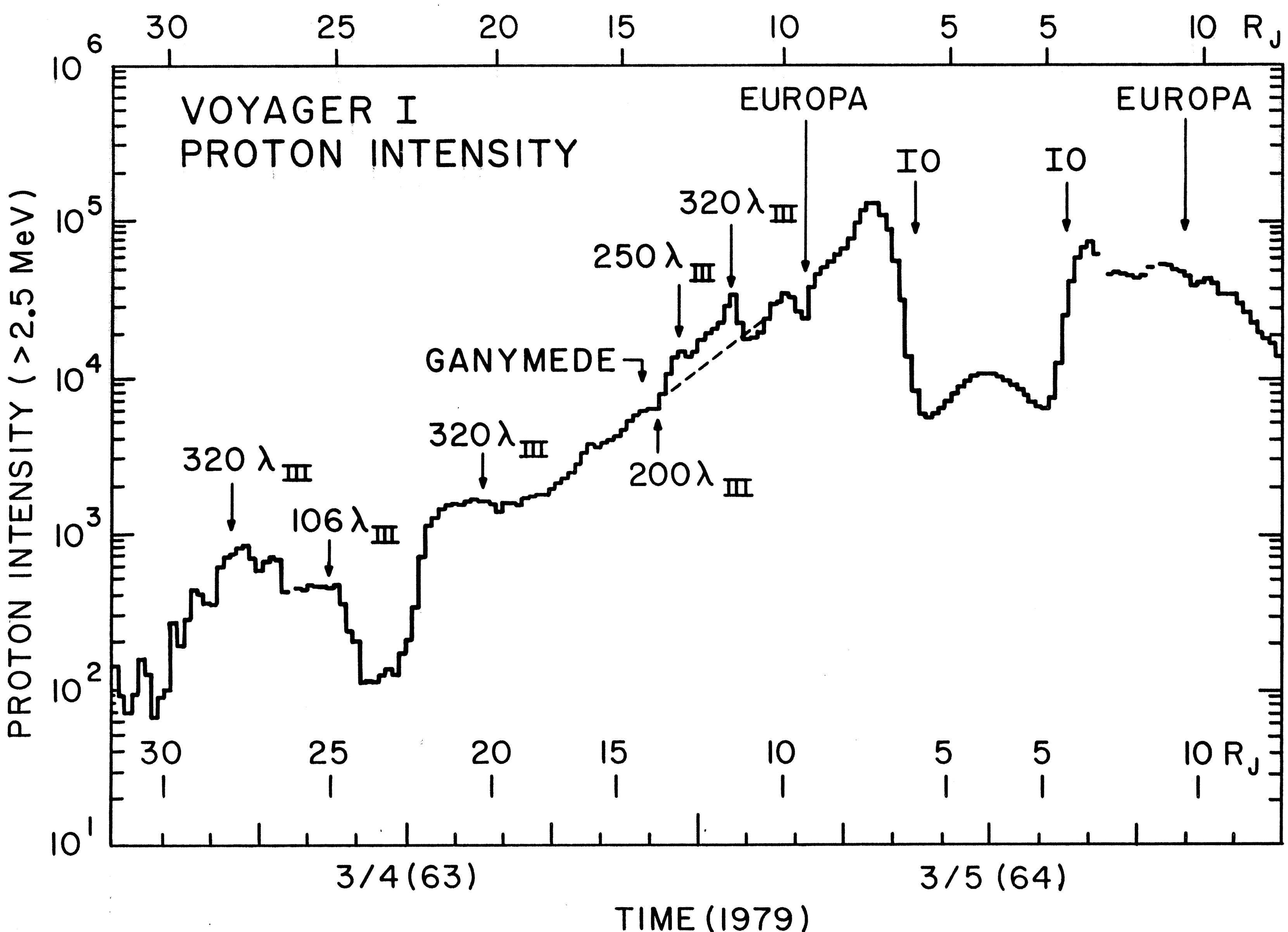

Fig. 4. Relative proton intensities in the middle magnetosphere observed with Voyager 1. Due to the extreme fluxes, the detector threshold shifted with counting rate.

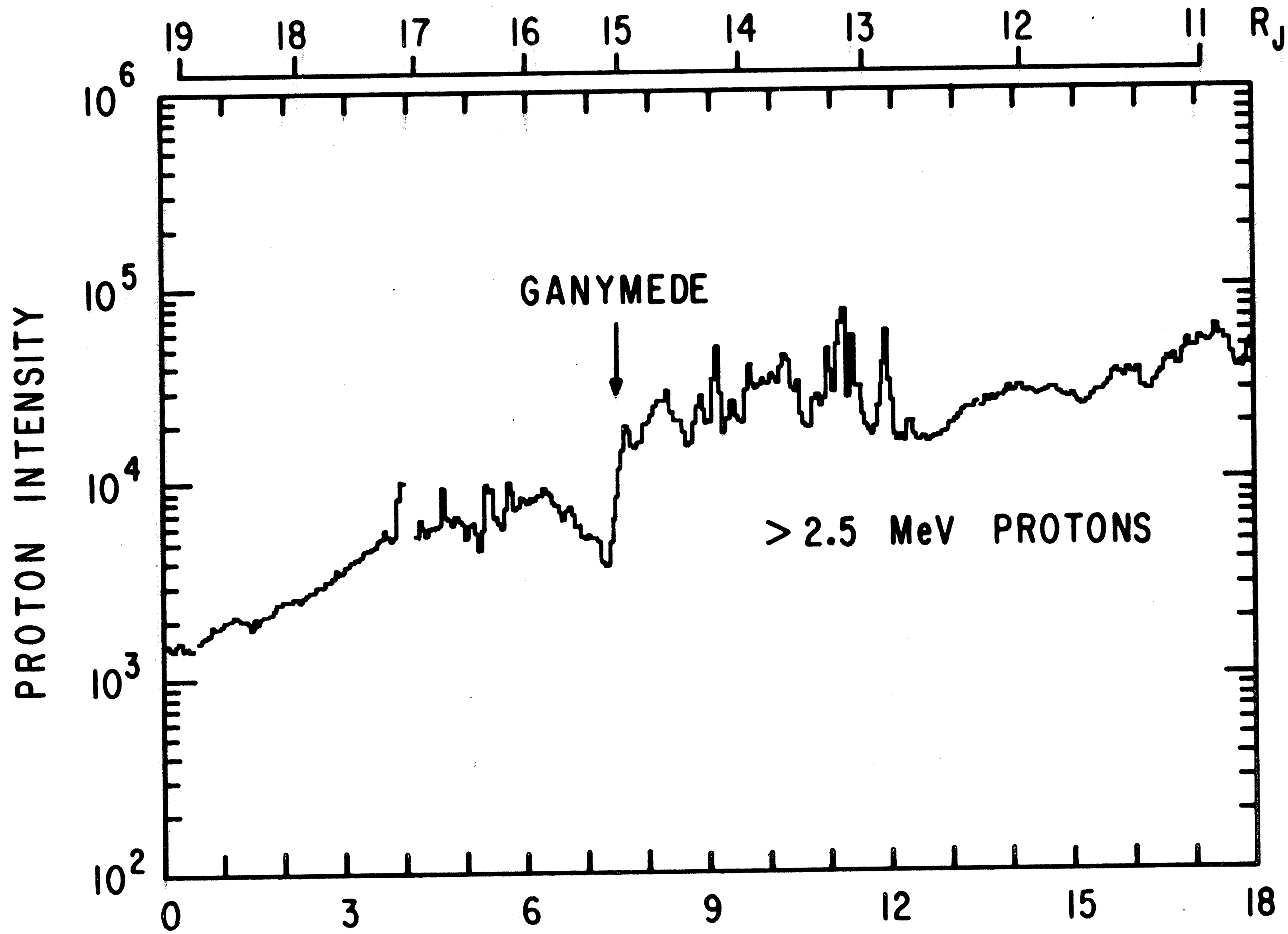

Fig. 5. Approximate intensity of protons with energies above 2.5 MeV observed with Voyager 2 near the orbit of Ganymede. Note the large intensity fluctuations which fall within ±4 hours of the closest approach to Ganymede.

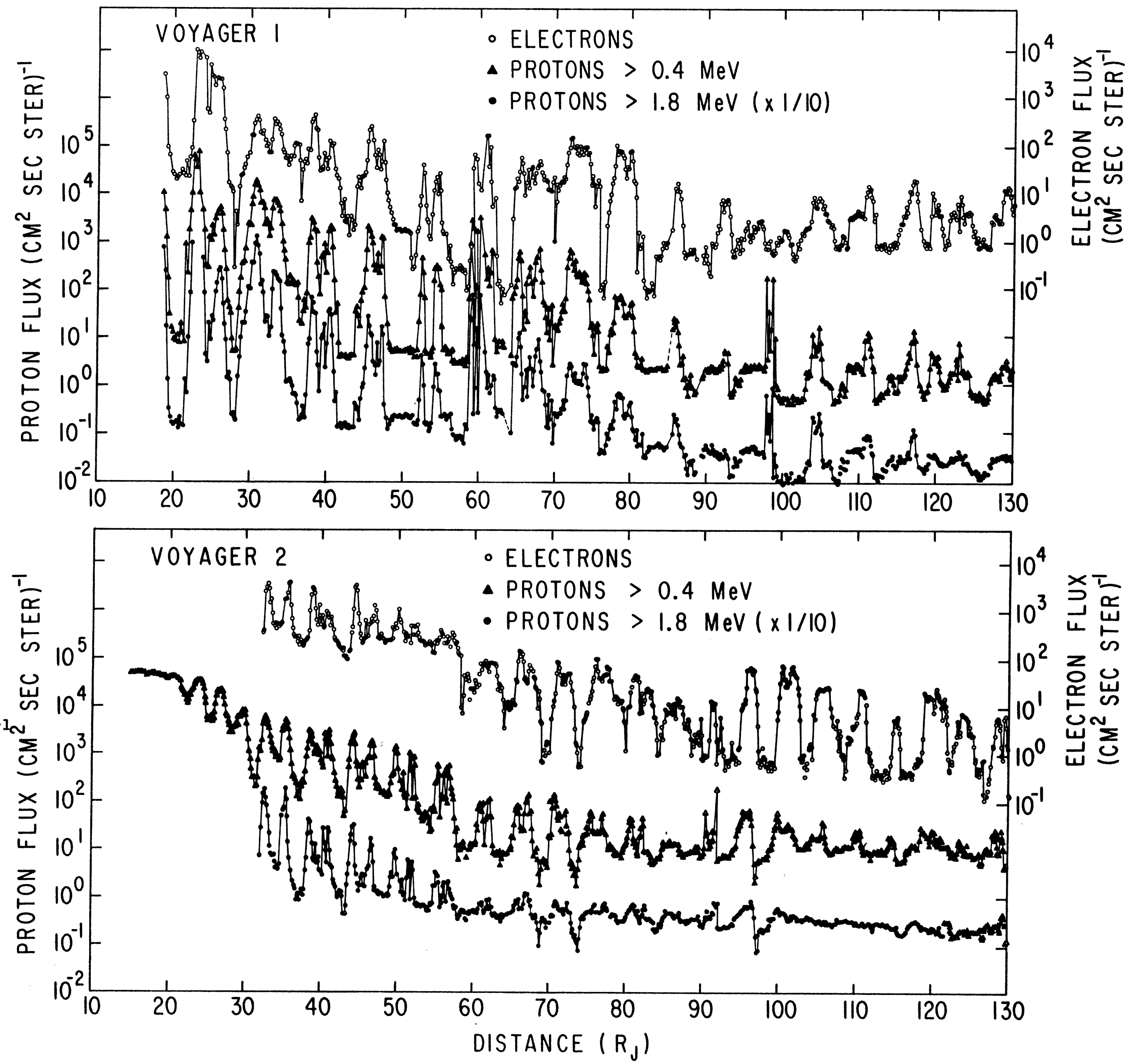

Fig. 6. Electron (2.6–5.1 MeV) and proton fluxes observed during the outbound passes of Voyagers 1 and 2. Electron and > 1.8 MeV proton fluxes above $10^3 cm^{-2}s^{-1}sr^{-1}$ are uncertain because of large corrections and show only relative trends.

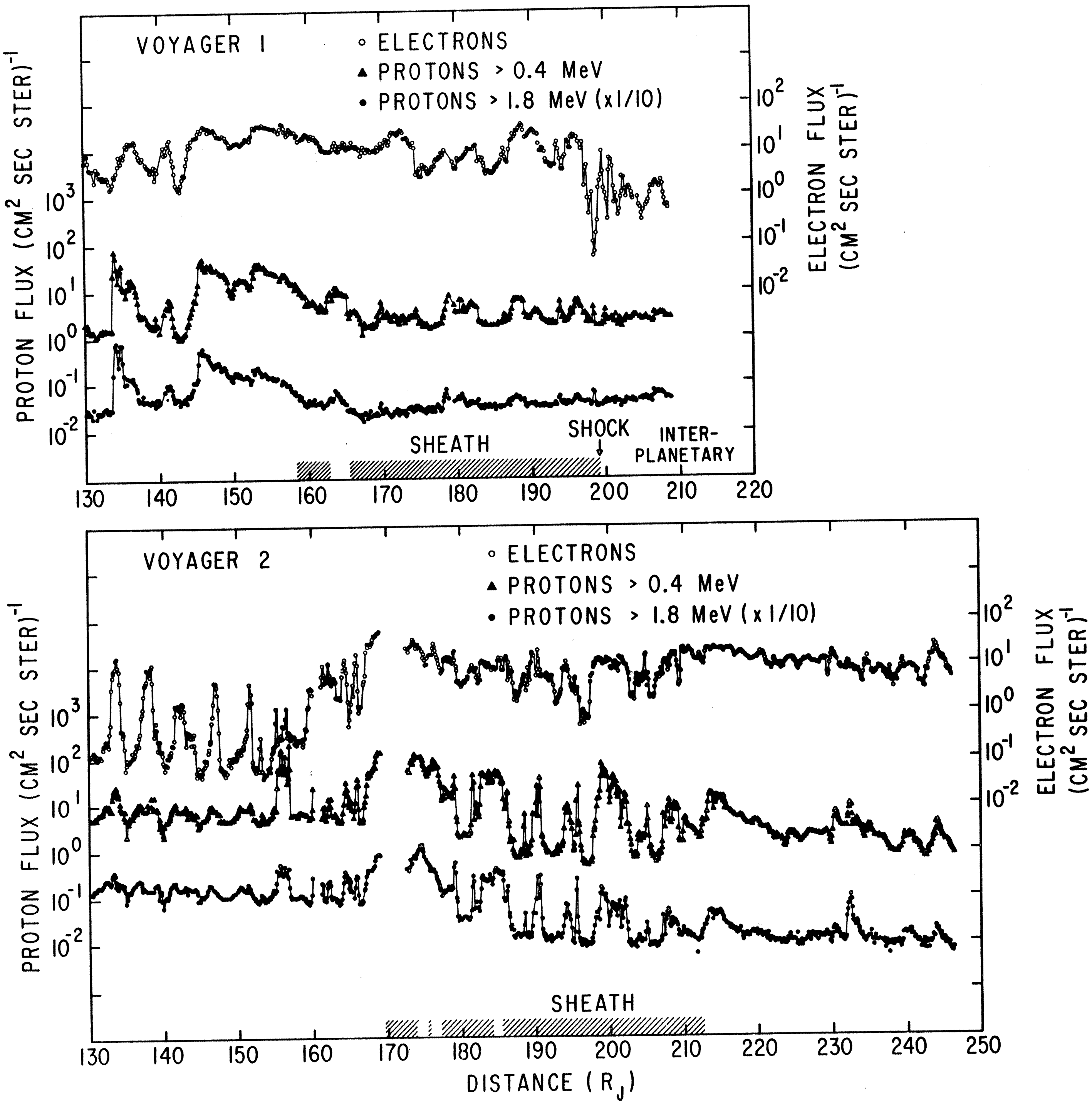

Fig. 7. The fluxes shown in Fig. 6 are extended from 130 to 250 Jovian radii. The shading near the distance scale indicates when the spacecraft were in the magnetotail.